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Black Spruce Cone and Seed Production : Yields from Ontario Collections

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ABSTRACT

Several black spruce cone and seed yield studies conducted by scientists of the Ontario Ministry of Natural Resources and the Canadian Forest Service are reviewed. Data on yields per tree, yields per hectolitre of cones, and yields per hectare spanning many years of production is listed. The information derived from these studies are suggested as a reasonable basis for planning cone and seed production strategies for black spruce in Ontario.

INTRODUCTION

Black spruce (Picea mariana (Mill.) B.S.P.) occurs across Canada (Vincent 1965). The species is commonly found in pure stands on a variety of peatland sites, and in mixed stands on upland mineral soil sites (Haavisto 1982). It is an important component of jack pine (Pinus banksiana Lamb.) forests on sandy sites, usually as an understory. Black spruce is primarily a boreal forest species, though its range does extend into northeastern and north central United States (Harlow and Harrar 1969). Due to its superior fibre quality, the species is the predominant raw material for the Canadian pulp and paper industry (Vincent 1965).

In the province of Ontario, forest land dominated by black spruce covers an estimated 17.4 million hectares (Ketcheson and Jeglum 1972). This represents approximately 41% of the Province's productive forest land. From this land base, about 61,000 hectares are harvested annually representing 38% of the annual coniferous wood harvested. An average of 33,700 hectares (55%) of the annual harvest requires regeneration assistance (Haavisto 1980). The need for a concerted artificial regeneration effort is therefore imperative. To accomplish this, large quantities of seed are required.

Planning for seed production and seed collection targets, to meet regeneration needs, is dependent on reliable information on cone and seed yield and quality. Some of the black spruce data in the Manual of Seed Collecting (Anonymous 1977), generally used in the Province of Ontario, contrasts sharply with the generally accepted North American authority, Seeds of Woody Plants in the United States (Schopmeyer 1974) and other published data (Appendix 1).

During the 20-year-period (1964-1984), both the Ontario Tree Improvement and Forest Biomass Institute (OTIFBI), Ministry of Natural Resources, and the Great Lakes Forestry Centre (GLFC), Canadian Forest Service, have undertaken numerous collections in Ontario for a variety of black spruce cone and seed studies. Yield data from over 3,300 individual tree collections has been assembled.

The intent of this paper is (a) to summarize research results to date on cone and seed production in black spruce, (b) to identify factors influencing cone and seed yields, and (c) to provide additional baseline information to facilitate the forest manager's implementation of meaningful strategies.

Subsequent papers will focus on individual factors that influence seed yield and quality such as cone size, cone age, stand type and treatment, time of collection, etc. This information should help narrow the gaps in our knowledge and allow the management specialists to manipulate these factors to their advantage. Such data should be under constant revision as new yield data becomes available and particularly for sources intensively managed for seed production.

METHODS: PROJECTS REVIEWED

In order to better understand the dynamics of black spruce cone and seed production, many individual tree collections have been made and valuable data generated. To evaluate cone production norms, nine studies

were selected. Locations across northern Ontario as numbered below are recorded on Figure 1. Data from these collections were listed and then synthesized to produce cone and seed yields on a per tree, per hectare and per hectolitre basis.

In order to provide a perspective on the objectives, methodologies and types of information obtained, each project has been briefly summarized. In each project, unless otherwise noted, collections were made by seed research staff from OTIFBI and/or GLFC.

(1) Monitoring black spruce cone and seed yields of natural stands, 1980-1982.

A project was initiated in 1979* to evaluate normal cone and seed yields per tree and per hectare in natural stands across northern Ontario. Fifteen plots were established near Sioux Lookout, thirteen near Geraldton, eight near Hearst, and six near Cochrane (Fig. 1). Plots were selected in fully stocked site class 1 upland sites (Plonski 1981) over a range of stand age classes. Annual collections were made by cone age classes over a three year period from five felled trees adjacent to each of the 42 plots. In the Hearst and Cochrane plots, as no cones were produced during 1980 or 1981, only 1982 cones were collected. A total of 490 trees were felled.

(2) The influence of cone size on seed yield and quality, 1979.

Collections were made in four seed production areas (Fig. 1). Trees were selected to give a range in cone size in each location. For three additional stands, cones of individual trees were collected by district staff from Red Lake, Ignace and Sioux Lookout. In each case total tree collections were made, and cones sorted into one of five size classes. Seed was extracted and cleaned separately for each cone size class by tree. Data was obtained from a total of 111 trees.

(3) Monitoring black spruce cone and seed yields from registered seed production areas, 1980-1984.

This project was similar to Project (1), except that annual cone collections were from numbered trees in permanent plots. Collections were made over a five year period to evaluate patterns of cone production and seed quality as influenced by individual tree, crop year, age of stand, and cone/seed relationships. A total of 100 trees were examined annually in each of four seed production areas in Nipigon (2), Geraldton (1) and Kapuskasing (1) Districts (Fig. 1). Not every tree produced cones in any one year. A total of 565 individual tree collections were made.

More detailed studies were initiated in 1982 in the Kimberly-Clark Canada Ltd. black spruce clonal seed orchard near Longlac. Three hundred and twenty trees were assessed in this latter study.

(4) Northwestern Ontario gene pool collections, 1979.

Over 3,000 'superior' black spruce trees were selected on a phenotypic basis by staff of the six administrative districts of Northwestern Ontario

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* Baker W.D. (1980). Black spruce cone and seed quality and quantity in relation to geographic location, stand age and cone age. Internal project proposal, Ontario Ministry of Natural Resources.

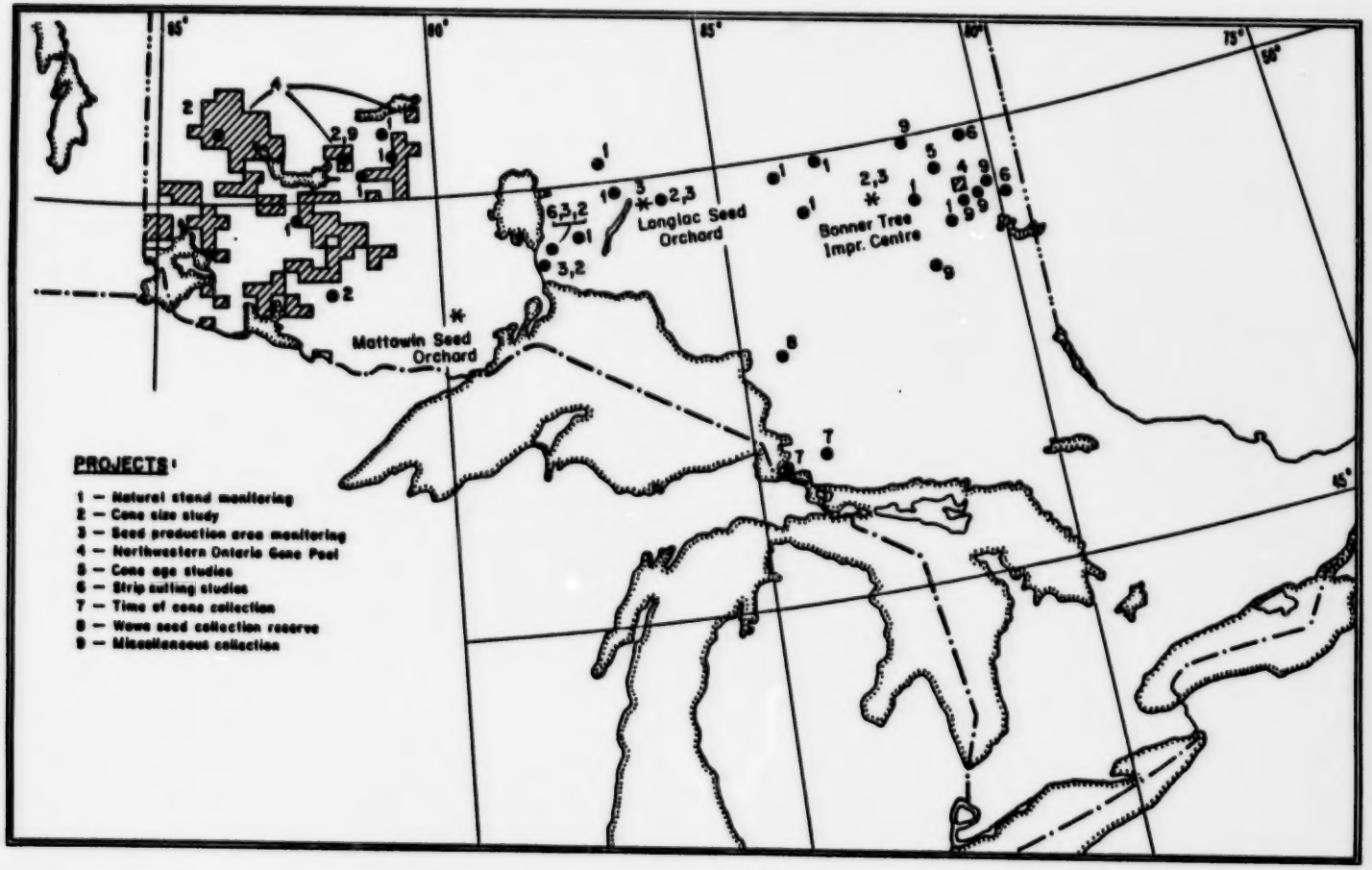
Mattawin Seed Orchard
Longlac Seed Orchard
Bonner Tree Impr. Centre
PROJECTS:
1 — Natural stand monitoring
2 — Cone size study
3 — Seed production area monitoring
4 — Northwestern Ontario Gene Pool
5 — Cone age studies
6 — Strip cutting studies
7 — Time of cone collection
8 — Wawa seed collection reserve
9 — Miscellaneous collection

Fig. 1. Black spruce cone and seed yield project sites in Ontario.

(Fig. 1). Current-year cones were collected and forwarded to the Ontario Tree Seed Plant for extraction. Cone counts were made, total cleaned seed weights were determined, and mean seed weights calculated for a total of 2,066 individual trees.

(5) A study of seed yield and quality relative to cone age from peatland black spruce, 1964-1967.

Over a period of four years, collections were made from five trees per year from merchantable black spruce stands in the Clay Belt of Northern Ontario (Rowe 1972). All cones were aged and kept separate by production year. Seed was obtained by using three cycles of extraction. Empty seeds were removed by flotation in a 10% ethanol solution. Total seed counts were recorded, and per cone seed yields were calculated. A total of 20 trees were collected.

(6) Evaluation of potential seed for regeneration of strip cuts in peatlands, 1975 and 1981.

In order to evaluate the availability of seed for regenerating strip cuts, investigations were conducted in Northeastern Ontario in 1975 and the Nipigon District in North Central Ontario in 1981 (Fig. 1). Cone collections were made from edge trees in the uncut strips. Cone volumes were measured and seed extracted on an individual tree basis. Cones were collected from a total of 24 trees.

(7) The influence of time of collection on seed quality, 1977.

Ten trees on each of two sites in the Sault Ste. Marie area, one peatland and one sandy-loam upland were selected. Twenty cones were randomly collected from each tree on a weekly basis between the last week of July and the middle of September when all the remaining cones were harvested. In addition, an area of naturally regenerated black spruce, 2.5 - 4.0 m tall was selected in Northeastern Ontario (Fig. 1). Cones were sampled sequentially, but with total tree collections made from 5 trees at two week intervals. Cone lots were immediately processed on an individual tree basis. Total per-tree cone volumes were ascertained. Cones from a total of 40 trees were collected.

(8) Estimation of cone crops in a seed collection reserve in Wawa, 1978, 1982 and 1984. (CFS/OTIFBI)

Two stands (Roy and Naganosh Twps.) were selected for development as future black spruce seed production areas. Twenty-six trees were randomly selected, felled, and cones collected during 1978 and 1982. Cone collections were made from 40 additional trees felled during 1984 for stem analyses. Cone counts and volumes per tree were recorded. Cones from a total of 66 tops were collected.

(9) Miscellaneous collections.

Data from other collections has been included where information was relevant. During feasibility studies on proposed mechanization of cone collection, considerable field work was initiated to ascertain numbers and volumes of cones per top. Some work was conducted on evaluation of two seed production areas. Studies of losses from flowering to seed maturity provided cone and seed yield information. Numerous other investigations have been conducted but data was considered inappropriate or inadequate for the purpose of this review.

RESULTS AND DISCUSSION

Cone and seed yields by project, location and year of collection are presented in Appendix 2. Since data was collected for different purposes in each project, not all sections of the table are complete. Only information for the current year's cones are presented. Seed data is recorded as cleaned seed unless otherwise noted. It is of concern that various authors provided seed yield data based on total, extracted, cleaned, filled or viable seed making comparisons and interpretations difficult. Furthermore, these can be complicated by different extraction methodologies used at different centres.

Very few of the cone crops recorded here can be classed as heavy, making it difficult to assess maximum crop parameters with confidence. Additional data will be required to exemplify yields from bumper crops.

Yields per tree:

Mean yields per tree are given in Table 1. As a general rule, collections as normally carried out in Ontario from unmanaged natural stands, can be expected to yield about one litre of cones or an average of 400 cones per tree. From these, seed yields average 9 grams, or about 9,000 cleaned seed per tree. Expected cone yields are considerably lower than the 1.8 to 14.1 litres reported by Safford (1974) or 36 litres per tree recorded in Anonymous (1977). Very few highly productive individual trees in managed stands reported here in bumper crop years achieved yields approaching these levels.

Crop year significantly influenced cone and seed production. For example, nil or only light cone crops occurred over an eight year period in northeastern Ontario, the lack of seed hindering regeneration efforts. Only two collections noted in Appendix 2 could be considered as

TABLE 1 Mean cone and seed yields per tree

Age Class	Cone Vol (l)	No. Cones	Wt Seed (g)	No Seeds
1-20 $\bar{x}$	0.8	220	8.3	7650
Range*	0.1-2.1	50-370	0.8-18.9	750-19500
21-40 $\bar{x}$	1.1	350	8.0	8050
Range	0.6-1.8	200-500	3.2-15.5	3200-14800
41-80 $\bar{x}$	1.2	460	10.7	12700
Range	0.3-5.8	100-2400	1.8-42.5	1800-57100
81-120 $\bar{x}$	1.0	525	7.9	8100
Range	0.6-1.7	120-1475	2.5-13.9	1200-15800
Overall crop estimate	1.0 l	400 cones	9.0 g	9000 seeds

* Range represents variation in mean values.

representing heavy crop years. Red Lake 1979 averaged 5.4 litres of cones (2400 cones) per tree yielding 33 grams (about 40,000) of cleaned seed. At Lydia Lake in the same year, a somewhat younger stand sampled trees produced an average of 5.8 litres (2000 cones) per tree, yielding 42 grams (about 57,000) of cleaned seed. One tree in the latter collection produced 10.9 litres of cones. Two others produced 2712 and 2843 cones. In both locations trees were selected for their heavy crops.

Stand age is one of the more apparent factors influencing cone and seed production. Young stands averaged 0.8 litres of cones per tree, while mean production peaked in the 41-80 year age class at 1.2 litres per tree. Cone production was lower in the overmature age classes. Though mean cone volume per tree differences were not large, the average number of cones per tree was found to increase considerably with age of stand. It follows that average cone size decreases with tree age. As a consequence, more than twice as many cones would need to be picked from older trees than from trees in the youngest age class to achieve a similar volume of cones.

Fig. 2. Matawin Black Spruce Seed Orchard, Thunder Bay District

The influence that tree age and cone size has on seed yields has been addressed by numerous authors. Waldron (1957) found that for a given site and stand density, older trees produced more cones than younger trees. He recorded a mean value of 868 cones per tree, similar to a maximum of 800 cones per tree estimated by Miller (1936). Haavisto (1975) and Prevost (1986) have reported mean values in excess of 1100 cones per tree. Haavisto noted that one dominant crown class black spruce produced 2865 cones in 1964, similar to the yields of the two Lydia Lake trees noted above. Others have reported yields of 100-200 cones per tree (Long 1946, Kokocinski 1978, Hall 1981, McPherson et al. 1982). Manley (1978) found well below 100 cones per tree in 12 and 13 year old stands. Long (1946) suggested that cone yield might be greater than 200 per tree in a good seed year. The expectation would be that large trees might outproduce smaller trees by a factor of two. Volumetric data is limited in literature but Smith and Woodcock (1980) reported an average of 1.0 litres per top based on a 400-top sample, mainly from mature and overmature peatland stands.

There is some indication that stands selected and managed for seed production yield considerably in excess of wild stands of a similar age. The Limestone Lake, Jean Lake and Bonner Centre Seed Production Areas (SPA) all outperformed the wild stands of Sioux Lookout and Geraldton during 1980 and 1982 (Appendix 2, Projects 1 and 3). Limestone Lake is a vigorous 20 year old plantation, while Jean Lake is a naturally regenerated seed production area of the same age. The latter exhibits a wide range in tree

size and produces fewer cones and seeds per tree (Appendix 2, Project 3). The best yields per tree in these projects have been from Limestone Lake in 1982 and 1984 when 83% and 91% of marked trees produced a cone crop averaging 1.73 and 1.80 litres per tree respectively. At the Bonner Centre (1984) where 89% of trees exhibited at least a light cone crop, a sample of 24 trees averaged 3.33 litres of cones. Seed extracted from these collections substantiate Waldron's (1957) yields of 15.2 grams (13,800) of cleaned seed per tree.

Site productivity no doubt affects cone and seed yield but is difficult to quantify from these projects. For comparable ages of trees, those on peatland sites produce fewer and smaller cones yielding fewer seeds per cone than those from uplands. Two stands in the same geographic range, already noted, support these observations. Limestone Lake trees are growing on a productive, fresh dolomitic limestone site. Jean Lake, situated on a moist boulder pavement, has developed less vigorous trees with cone yields of half to two-thirds those of Limestone Lake. Furthermore, the cones are smaller and seed yields lower.

Fig. 3. Black Spruce cones on young plantation tree, Limestone Lake, Nipigon District

Differences in yield per tree are also related to stand and site conditions. The authors' observations over the duration of these studies suggest much larger crops of larger cones yielding more seed per cone on trees growing on upland sites. Simpson and Powell (1981) noted a larger proportion of trees on southerly sites producing cones, and cone bearing trees producing 2.5 times as many cones as those on northerly aspects or double the yield of trees on level sites. Differences between Limestone Lake and Jean Lake collections are of a similar magnitude though site differences have influenced growth resulting in tree size differences as well. There is inadequate information in projects reported here to assess the influence of site factors on cone and seed yield and quality. Considerably more study is required particularly on site factors to consider in establishment of seed orchards and management of seed production areas.

Yields per hectolitre:

Mean cone and seed yield data for the 9 projects is summarized on a per hectolitre basis in Table 2. In most cases, the range in values is similar to that in current published usage (Safford 1974, Anonymous 1977). The mean numbers of cones per hectolitre reported here lie within the ranges published; ie. 19,200 - 44,000. Millar (1936) reported 19,700, 24,900 and 36,520 cones per hectolitre depending on site.

The most significant factor influencing the number of cones per hectolitre are tree age and cone size. Cone size decreases with age of tree. Collections from young stands averaged 27,300 cones per hectolitre while those from older stands averaged 40,200 (Table 2). This juvenile cone production characteristic is most apparent in the Limestone Lake collections during 1979 and 1982 (17,400 cones/hl), and appears to be retained to at least 28 years of age in the Bonner Centre collections (1982 - 26,200 cones/hl). Similar data from the Kimberly-Clark clonal seed orchard at Longlac, Ontario indicates that this juvenile characteristic is maintained through clonal propagation for at least 20 years (26,500 and 28,200 cones/hl in 1982 and 1984, respectively). For collections from older stands, mean values were recorded up to 61,600 cones per hectolitre in one Sioux Lookout collection, while one individual tree in Hearst produced very small cones, requiring 96,900 cones for one hectolitre. No

TABLE 2 Mean cone and seed yields per hectolitre

Age Class	No. of cones	No. of seeds (M)	Wt. of seed (kg)	Seeds (M/kg)
Young Managed Stands				
$\bar{x}$	25,600	777	.86	900
Range	17,400-31,500	450-938	.54-1.06	
Young Wild Stands				
$\bar{x}$	29,100	824	.92	900
Range	26,500-34,000	609-1,202	.73-1.19	
21-40				
$\bar{x}$	35,000	722	.68	1060
Range	24,200-43,700	610-895	.57-0.92	
41-80				
$\bar{x}$	41,400	833	.76	1100
Range	31,400-61,600	488-1,190	.44-1.04	
81-120				
$\bar{x}$	44,300	700	.65	1080
Range	34,800-51,000	488-1,110	.40-0.96	
Young stands	27,300 cones/hl	800,000 seeds/hl	.90 kg seed/hl	900
Older stands	40,200 cones/hl	750,000 seeds/hl	.70 kg seed/hl	1080

mature trees in these studies produced the large cones typical of young stands, but some individual young trees exhibited cone sizes more typical of older trees. Tree to tree variation in this characteristic was found to be very great.

Cone size also appears to be related to crop year. In 1979 and 1982, cones from Limestone Lake averaged 17,400 cones per hectolitre while the cones in the 1980 and 1981 collections were considerably smaller, averaging 27,000 and 28,600 cones per hectolitre respectively. Differences between years were also considerable over the three year period of monitoring Geraldton and Sioux Lookout stands. These collections, however, were based on felled trees, hence different trees each year.

Considerable variation in yields of cleaned seed per hectolitre was found in this study, and ranged from 450,000 to 1,202,000 seeds. Similar variability has been noted by others (Appendix 1). These overall averages are well below the numbers reported by Millar (1936) in three separate collections, one as high as 2 million seeds. Generally, the collections in the studies reported here yielded 725,000 to 835,000 seeds per hectolitre. No pronounced trends were detected. The youngest stands tended to produce marginally more seed per hectolitre (800,000) than older stands (750,000). An overall estimate of 775,000 seeds per hectolitre is suggested.

A relationship is indicated between weight of seed per hectolitre and stand age. Cones from young stands yielded 0.9 kilograms of seeds per hectolitre of cones, while those from older stands yielded about 0.7 kilograms (Table 2). This reflects a difference in seed weight from 1.1 mg/seed in younger stands to 0.9 mg/seed in older stands. The Manual of Seed Collecting (Anonymous 1977) suggests a seed yield of 0.5 kilograms of seed per hectolitre. Safford (1974) records lower yields (0.15 to 0.39 kg/hl) as did Stoekler & Jones (1957) (0.31 kg/hl). Millar (1936), however, reported much higher yields of 1.28 to 1.59 kg/hl.

The number of seeds per kilogram is influenced by age of stand (Table 2). Seed from young stands averaged 900,000 per kilogram, whereas older stands produced yields slightly higher (1.1 million seeds/kg). This is similar to data reported by Millar (1936), Stoekler & Jones (1957), Hoekstra et al. (1961), Safford (1974), Anonymous (1977), and McCaughey et al. (1986). Hall (1981) reported heavier seed (700,000 seeds/kg), while Miller (1936) and Manley (1978) reported much higher numbers of seed, ranging between 1.5 and 1.9 million seeds/kg).

The number and weight of seed per kilogram of cleaned seed reported by various authors is highly dependent on the extraction methodologies. It has been suggested (Schooley*, pers. commun.) that variability in yields due to processing technology has in the past exceeded that due to biological causes such as ineffective pollination, degree of seed set and damage due to insect, disease and other biotic influences.

Yields per hectare:

There is a dearth of area based information. In these studies, information only from projects 1 and 3 can be used.

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* Schooley, H.O., National Tree Seed Centre,
Petawawa National Forestry Institute

In young managed seed production areas, a mean value of 20 hl of cones and 18 kg of seed per hectare were obtained (Table 3). The highest production of 43 hectolitres of cones and 38 kilograms of seed per hectare was recorded from Limestone Lake in 1982. Unmanaged young stands, however, produced only 20% of the average for areas managed for seed production.

Mature natural stands produced 9-13 hectolitres per hectare yielding 6-9 kilograms of seed (Table 3). Differences were attributable to year of collection. A maximum of 20 hectolitres of cones and 16 kilograms of seed per hectare in the 41-80 year age class was recorded for Sioux Lookout in 1981.

These data are considerably higher than those reported by most authors. Based on the figure of 900,000 seed per kilogram, natural upland stands in Table 3 would produce 2-9 to 8.1 million seed per hectare, while young stands managed for seed production would average 16.5 million seed. Others have estimated 0.5 to 1.6 million seed per hectare (Johnson 1977, Manley 1978, McPherson et al. 1982), while Anonymous (1939a) reported 1.0 to 6.3 million seed per hectare for stands on wetland and upland sites respectively.

Seed fall ranging from 350,000 to 1,250,000 seeds per hectare (Anonymous 1939b), Heinselman 1957, Fowells 1965, Haavisto 1975) has been reported. Losee (1961) with a limited number of traps, found annual seedfalls of 1.0 to 12.7 million seeds per hectare. Lebarron (1948) reported that seedfall on upland sites (1.1 million seeds per hectare) was

TABLE 3 Seed and cone yields per hectare, and seeds/cone

	Vol cones (hl/ha)	Wt of seed (kg/ha)	Seeds/cone
Young managed stands	19.80 5.20-43.25	18.3 2.8-38.0	35.7 13.1-64.2
Young natural stands	3.28 .16- 8.39	3.2 0.2- 7.8	28.3 10.1-39.3
21-40	9.32 5.42-13.59	6.4 3.1- 9.0	22.7 18.6-34.4
41-80	11.35 4.44-20.17	9.0 2.3-15.9	24.1* 12.8-49.0* (25.3)
81-120	12.55 8.62-15.39	8.3 3.6-14.7	16.1 10.9-20.9

* Summary of project means includes 2 collections from a 41-80 age class managed S.P.A. averaging 28.9 seeds per cone in Lydia Lake and 2 collections from the 21-40 year age class young stands averaging 40.6 seeds/cone (5 extractions) in Roy Twp. and Fraserdale. Without this data the means of the remaining 8 collections averaged 18.8 seeds/cone.

more than double that on lowlands (0.5 million) between 1935 and 1939. Howard (1963) reported a seedfall of 2.4 million seeds per hectare in Newfoundland over a one-year period. Haavisto (1975) found almost two thirds of trapped seedfall was empty seed. Seedfall information cannot be directly related to seed production data due to the semi-serotinous nature of black spruce cones.

The numbers of seed per cone appears to decrease from 36 and 28 in young managed and unmanaged stands respectively, to 16 in overmature stands (Table 3). This trial possibly reflects both decreasing numbers of seed produced and seeds extracted. Lydia Lake, a thinned stand, produced higher numbers of seed per cone. Similarly, collections from Roy Twp. and Fraserdale, subjected to 5 cycles of extraction, produced more than double the number of seeds. A decreasing cone size in older trees may result in both fewer seeds per cone and increasing difficulty in seed extraction.

Fig. 4. Collection of Black Spruce cones with tripod ladder, Kimberly-Clark

Mean yields in these studies ranged from 10-64 seeds per cone. Chai and Hansen (1952), Haig (1969), and Haig and McPhee (1969) reported seed yields in this range. Manley (1978) reported yields of 42-56 seeds per cone from 12 and 13 year old trees. Millar (1936) reported yields of 55-69 seeds per cone depending on site type. Stoehr (1985) reported 71.2 seeds per cone in a young seed orchard (based on total seed from dissected cones) in contrast to McPherson et al. (1982) who extracted only 11.0 filled seeds per cone. Millar (1936), Waldron (1957), Haavisto (1975), Morgenstern et al. (1975), Stoehr (1985), McCaughey et al. (1986), found fewer seeds in cones from stands on peatland sites than from those on upland mineral soil sites. Much of the wide variation in yield per cone may be due to different seed extraction techniques and different bases for reporting; ie. total, extracted, cleaned, sound or viable seed.

CONCLUSIONS

Reported black spruce cone production and seed yields vary considerably. Data from over 3300 individual tree collections show wide variability. This information is presented to (1) provide general indications of probable yields under a range of situations, (2) identify factors influencing such variation, and (3) to identify gaps in our knowledge whether related to the trees, their environment or outside biotic or abiotic factors.

As operational cone collections are usually made during good crop years, the information of greatest value is the upper limit of cone and seed production. Unfortunately, most cone collections were made in other than bumper cone years. However, collections from the young stands at Limestone Lake and Jean Lake in 1982 may well approximate maximum yields from young trees. Had a larger sample been taken from the mature stands at Lydia Lake and Red Lake in 1979, the average 5 litres of cones per tree might not have been so high. Nevertheless, the figure is of value since the information on upper yield is the more important consideration for planning purposes. It is generally accepted that the highest quality of seed and best yields are obtained during good cone years. Operational collections should be concentrated in heavy crop years to optimize return on dollars invested.

Cone and seed information in the planning processes must recognize practical considerations in the field. Cone pickers will be selective. It takes as long to pick a large cone as a small one, so preference will be given to crowns with large cones. Similarly, large crops per tree will generally be selected by the pickers whether cones are to be removed manually or mechanically. On this basis, mean yields per tree in practice could be greater than the data presented here.

The bases on which seed yields are reported require clarification. Comparative studies are imperative to relate differences between total extracted, cleaned, sound, and viable seed. Processing techniques in terms of extraction and cleaning must be clearly defined when reporting results. It would be most desirable to have standard procedures which optimize yields and produce quality seed from black spruce cones. Subsequent papers will address the numerous factors influencing seed yield using the data summarized above.

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APPENDIX 1 Published Cone and Seed Yield Information

References Name - date	Stand or tree age	# of trees	Cones/tree		Seed/tree		Cone & seed/hectolitre			Seeds per cone	Mean seed wt. (mg)	# seeds per kilogram	Cones and Seed/hectare				Remarks
			# of cones	Vol. (L)	Wt.of seed (g)	# of seed	# of cones	Wt. of seed (kg)	# seed				Vol.of cones (HL)	# of cones	#'s of seed	Wt.of seed (kg)	
Anonymous 1939a	100+	25													1,027,900		'36 swamp
	100+	25													951,300		'37
															219,900		'38
															6,259,000		'36 upland
															926,600		'37
															1,816,100		'38
Anonymous 1948				1.8-14.5													See also Safford 1974
Anonymous 1977			(6,912-18,840)	36	(0.18)	(158400)	19,200-44,000	0.500	(440,000)	(10.0-22.9)	1.13	880,000					Mean values range
											1.42	704,000-					
											-0.95	1,056,000					
Anonymous 1986								0.404	352,555V		1.15	873,000					
Chai & Hansen 1952	100+	20								50	0.64						Swamp trees
Dobbs et al 1976								0.063	50,600V			851,400					Basis:
									27,500-			679,800-					3 seedlots
									83,900			1,051,600					2.5 Hl cones
Fleming & Haavisto 1986	M&OM									82.6T							Complete extraction
										69.4-84.5							Incomplete extraction. 210 indiv. cones.
Fowells 1965												891,000					
Haavisto 1975	100+	20	792			(11,689)				14.4T							
										4.4S							
Haavisto 1982	18	5								22.1							
Haig 1969	100+							0.468		20.25							1967 crop
Haig & McPhee 1969	50							0.624		27.45							Undamaged
										22.75							Insect damaged
Hall 1981										40.0	1.43	700,000					1980

	Young		100				0.667		15.30			(2.850)	50000		1.9	1979 Young stands
							1.600					(1.187)			1.9	1980 collection on 400 ha. SPA
Hall 1986									31.4-37.1(T)							
									25.0-30.3(S)							2 years collections
									22.4-29.6(V)							
Ho 1987			82													5 year average
Hoekstra et al 1961										1.12	882,000					2-3 m trees
Janas & Haddon 1984							0.89	890,000*	30.7							Ontario
							0.16-0.88	160,000-880,000	5.6-30.3							Other provinces
								(*assume 1.0 mm/kg)								
Johnston 1977														494,200	0.227	Annual average
Kokocinski 1978		108														
LeBarron 1948														Wetlands		
														481,000		1936
														723,800		1937
														127,500		1938
														448,500		1939
														Uplands		
														4,080,400		1936
														635,700		1937
														1,470,600		1938
														237,200		1939
Long 1946			200													6" diameter trees
Manley 1978	12	41	20		(840)				42T 6S	(.57)	1,769,000		(35714)	1,500,000 (172,500S)	(0.848)	15% sound
	13	50	62		(3348)				54T 6S	(.51)	1,947,000					
Manley 1969									56							
McCaughey et al 1986											890,100					
McPherson et al 1982	8	436	103		(1133)				11F					994,000		Clonal seed orchard

APPENDIX 1 (cont'd)

References Name - date	Stand or tree age	# of trees	Cones/tree		Seed/tree		Cone & seed/hectolitre			Seeds per cone	Mean seed wt. (mg)	# seeds per kilogram	Cones and Seed/hectare				Remarks
			# of cones	Vol. (L)	Wt.of seed (g)	# of seed	# of cones	Wt. of seed (kg)	# seed				Vol.of cones (HL)	# of cones	#'s of seed	Wt.of seed (kg)	
Millar 1936			800 (max) 270 (partial seed yr)		(0.300)	(44000)	36,520	1.372	2,008,600	55	(.68)	1,464,400					Spruce-hardwood small cones
					(0.521)	(55200)	19,700	1.285	1,360,100	69	(.94)	1,058,900					Spruce-hardwood large cones
					(0.512)	(53000)	24,900	1.600	1,621,600	65	(.98)	1,015,400					Spruce swamp
Morgenstern et al 1975		125				(1625)				13							
Prevost 1986	30-35	10	88							39.4(T) 19.1(S) 13.8(V)							1983 unsprayed
		10	1140														1984 Unsprayed - total cones
			530														- sound cones
		3	990														1984 sprayed - total cones
			835														- sound cones
Rudolf 1959				4.0				0.31				890,800					Av year.
				9.0													Max in good seed year
Safford 1974									(138,964)			890,800					
							19,250	0.156	139,319	(7.2-7.9)	(1.12)	737,000-					Mean
							-44,000	-0.390	-348,300			1,122,000					range
Skeates 1972											.434	2,304,100					
											-1.540	-649,400					Bulk seed lot, sorted by seed weight
Smith & Woodcock 1980				1.0													
Stoekler & Jones 1957	100+	400						0.312	(268,289)		(1.16)	859,900					

Stoehr 1985	19									13F 71.2 48.7-100.0	1.18 0.94 -1.53	847,500					Range, mean clonal values
Thibault 1985	16		261.1	1.2	1.6	1296T 1140V		.129		3.4	1.3	810,300					Single extraction. Fertilized plantation.
			372.0	1.0	.7	536T 420V		.088		2.1		760,400					Unfertilized
Verheggen & Farmer 1983										33T 14 - 49							
Vincent 1966		10	67.5			1631.3				24.2T 7.7S							1965, 2 extractions. Est. 1/2 total seed.
Wang 1973								.40-.55									
Zasada & Viereck unpublished			278			12,000 (35,200 max.)				40							

NOTE: It is assumed most authors are quoting cleaned seed information. Where other values are indicated, this is noted.
(T = total seeds, S = sound seed, V = viable seed).
Figures in parentheses have been calculated from authors' published data.

APPENDIX 2 Mean Cone and Seed Yield Information from Ontario Projects

	Stand age Class	Coll. year	Yield per tree				Yield/hL			Seeds per cone	Yields/ha	
			No. Trees	Vol. cones L/tree	# cones per tree	Wt. cl. seed/tree (g)	# Cl. seed per tree	# Cones per hL	Wt. of seed per hL (kg)	# Seeds per hL (m)		Vol. cones per ha (L)	Wt. cl. seed per ha (kg)
1. Monitoring black spruce from natural stands (current cones only)													
Sioux Lookout	1-20	1980	15	.48	164	3.8	3,066	34,000	.73	609	17.7	433	3.4
	21-40		20	.66	260	4.0	4,338	39,300	.61	656	15.4	650	3.9
	41-80		20	.67	245	3.9	4,363	36,800	.58	655	17.4	1,136	6.6
	81-120		20	.78	357	3.5	3,695	46,100	.45	476	10.9	889	4.0
	1-20	1981	15	.44	125	3.3	2,920	26,500	.75	664	23.5	397	3.0
	21-40		20	1.38	508	8.5	9,540	36,700	.62	695	18.6	1,359	8.4
	41-80		20	1.19	484	9.4	10,640	38,700	.79	919	22.2	2,017	15.9
	81-120		20	1.68	662	9.0	9,736	42,400	.54	623	15.0	1,915	10.3
	1-20	1982	15	.93	302	8.6	8,001	32,200	.92	860	25.9	839	7.8
	21-40		20	1.21	529	9.1	10,132	43,700	.75	837	19.9	1,192	9.0
	41-80		20	0.72	444	7.5	8,565	61,600	1.04	1,190	18.8	1,220	12.7
	81-120		20	1.35	689	12.9	14,986	51,000	.96	1,110	19.9	1,539	14.7
Geraldton	1-20	1980	5	0.61	132	6.1	6,151	22,500	1.00	731	32.4	122	1.2
	21-40		25	1.06	274	6.5	6,283	24,200	.61	642	27.8	1,026	6.3
	41-80		10	0.82	331	3.6	3,918	41,800	.44	448	13.3	1,041	4.6
	81-120		25	0.62	231	2.5	2,668	34,800	.40	448	13.1	888	3.6
	1-20	1981	5	0.08	53	0.8	748	--	1.00	--	10.0	16	0.2
	21-40		25	0.56	209	3.2	3,214	37,700	.57	610	20.7	542	3.1
	41-80		10	0.35	146	1.8	1,796	42,500	.51	494	12.8	444	2.3
	81-120		25	0.85	429	5.4	6,356	46,200	.64	683	14.8	1,217	7.7
	1-20	1982	5	0.38	82	3.2	2,635	27,300	.84	878	27.8	76	0.6
	21-40		25	0.85	243	7.8	7,604	28,600	.92	895	32.1	823	7.6
	41-80		10	1.23	386	11.6	11,016	31,400	.94	896	25.8	1,562	14.7
	81-120		25	1.03	458	7.8	8,545	44,400	.76	830	17.6	1,475	11.2
Hearst	1-20	1982	5	0.75	242	8.9	7,745	32,300	1.19	1,202	37.2	510	6.0
	41-80		25	0.94	445	8.5	9,515	47,500	.90	846	17.8	1,658	15.0
	81-120		20	0.75	335	5.8	6,567	45,000	.77	726	16.8	862	6.7
Cochrane	41-80		30	1.17	444	9.4	9,858	37,900	.80	838	22.1	1,352	10.9

2. Influence of cone size on black spruce seed yield and quality													
Limestone Lake	1-20	1979	31	2.08	369	18.9	19,463	17,399	.91	938	52.5		
Jean Lake	1-20	1979	30	1.54	367	13.7	13,040	25,500	.89	867	37.0		
Bonner Centre	1-20	1979	15	1.12	292	8.4	8,520	26,555	.75	746	29.9		
Lydia Lake	41-80	1979	7	5.79	2,042	42.5	57,113	39,468	.73	1,115	28.6		
Sioux Lookout		1979	8	1.65	614	13.6	16,084	41,000	.82	974	24.6		
Ignace		1979	10	0.86	314	5.6	6,383	36,400	.65	691	22.6		
Red Lake		1979	10	5.35	2,431	32.8	39,351	45,000	.61	735	16.8		
3. Monitoring black spruce cone and seed yields from registered seed production stands													
Limestone Lake	1-20	1980	44	1.34	365	14.1	12,651	27,049	1.05	882	33.3	3350	35.2
		1981	50	0.36	104	2.9	2,272	28,600	.81	631	20.6	900	7.2
		1982	83	1.73	302	15.2	13,104	17,400	.88	757	44.6	4325	38.0
		1984	91	1.80	334	13.6	11,457	18,600	.75	636	35.6	4500	34.0
Jean Lake	1-20	1980	56	0.72	204	6.6	6,017	31,515	.92	846	28.5	1440	13.2
		1981	33	0.26	80	1.4	1,170	30,900	.54	450	13.1	520	2.8
		1982	49	0.67	172	6.7	6,137	25,800	1.00	916	36.4	1340	13.4
		1984	63	0.80	166	6.6	5,879	20,200	.83	735	36.0	1600	13.2
Bonner Cen.	21-40	1982	20	1.76	453	15.5	14,805	25,400	.88	841	32.9	1786	15.7
		1984	24	3.33	873	30.2	28,567	26,216	.91	858	36.7	3380	30.6
Lydia Lake	41-80	1982	49	0.82	280	7.4	7,526	36,200	.90	938	29.2		
Longlac S.O.		1982	200					26,500	.75	692	27.2		
		1984	120	2.50	704	14.5	14,721	28,200	.57	589	21.1	1580	9.2
4. Gene pool collections													
Dryden	81-120	1979	200		765	13.5	16,171				20.9		
Ignace			269		202	3.0	3,125				15.8		
			38		219	3.4	3,448				15.5		
			216		304	4.8	5,237				17.6		
Fort Frances			296		636	9.5	10,632				14.3		
			415		909	11.4	13,316				14.5		
Kenora			184		614	9.5	10,665				17.7		
			219		895	13.9	15,825				18.5		
Red Lake			149		866	10.7	13,243				16.3		
Sioux Lookout			230		880	7.9	10,494				13.0		
5. Seed yields relative to cone age of peatland black spruce													
Kennedy Twp.	81-120	1964	5		1,474		1,257				9.3		
		1965	5		135		1,231				5.5		
		1966	5		226		8,208				8.8		
		1967	5		929								

APPENDIX 2 (cont'd)

	Stand age Class	Coll. year	Yield per tree				Yield/hL			Seeds per cone	Yields/ha	
			No. Trees	Vol. cones L/tree	# cones per tree	Wt. cl. seed/tree (g)	# Cl. seed per seed	# Cones per hL	Wt. of seed per hL (kg)	# seeds per hL (m)		Vol. cones per ha (L)	Wt. cl. seed per ha (kg)
6. Evaluation of potential seed for natural regeneration in black spruce peatland strip cuts													
Case Twp.	81-120	1975	8		130								
Abitibi	81-120	1975	8	0.30	159		4,639	52,600		1,406	26.7*		
Nipigon	81-120	1981	8		120								
7. Influence of time of collection on seed quality, sequential collections through year of product													
Wade Lake	81-120	1977	30	0.15	37		1,169				33.4*		
	81-120	1977	20	0.15	37		1,274	24,600		844	39.3		
Dunn's Valley	21-40	1977	10	0.56	127		4,366	22,800		784	34.4		
Manitou Park	41-80	1977	10	1.07	334		11,677	31,600		1,131	35.8		
8. Cone crop evaluation, Wawa													
Roy Twp.	41-80	1978	4	0.26	108		3,892				32.2		
		1982	7	2.07	739			35,700					
		1982	15	0.89	326			36,600					
		1984	40										
9. Miscellaneous collections, Peatlands													
Fraserdale	41-80	1976/8	13	0.30	118			38,800					
Sioux Lookout	81-120	1979	8	0.22	38			17,800			64.2		
Timmins	81-120	1976	4		348		5,934				17.2		
(Insect Study)			12	1.75	909								
Hearst		1978	6					51,800					

* Filled seed